इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”
Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”

IS 9835-1 (2001): Series Capacitors for Power Systems, Part 1: General Performance, Testing and Rating - Safety Requirements - Guide for Installation [ETD 29: Power Capacitors]

“ज्ञान से एक नये भारत का निर्माण”
Satyanarayan Gangaram Pitroda
“Invent a New India Using Knowledge”

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”
Bhartṛhari—Nītiśatakam
“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE

BRUTUM FULMEN

IGNORANTIA JURIS NON EXCUSAT

PROTECTED BY COPYRIGHT

IS 9835 (Part 1) : 2001
IEC 60143-1 (1992)

भारतीय मानक

श्रेणी संधारित्र हेतु पावर प्रणाली

भाग 1 सामान्य कार्यकारिता, परीक्षण और रेटिंग – सुरक्षा अपेक्षाएँ – संस्थापन हेतु मार्गनिर्देश

(पहला पुनरीक्षण)

Indian Standard

SERIES CAPACITORS FOR POWER SYSTEMS

PART 1 GENERAL PERFORMANCE, TESTING AND RATING — SAFETY REQUIREMENTS — GUIDE FOR INSTALLATION

(First Revision)

ICS 31.060.70

© BIS 2001

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

January 2001

Price Group 13

Power Capacitors Sectional Committee, ET 29

NATIONAL FOREWORD

This standard (Part 1) (First Revision) which is identical with IEC 60143-1 (1992) 'Series capacitors for power systems — Part 1 : General performance, testing and rating — Safety requirements — Guide for installation' issued by the International Electrotechnical Commission (IEC), was adopted by the Bureau of Indian Standards on the recommendation of Power Capacitors Sectional Committee (ET 29) and approval of the Electrotechnical Division Council.

Only the English text of the IEC Publication has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not same as in IEC Publication.

This standard was first brought out in 1981 for standardizing the ratings, performance requirements and test methods for series capacitors. The first revision of this standard has been undertaken to align it with the work done at the International level.

This standard is one of the series which deals with series capacitors for power systems. The title and the No. of this IEC Publication [which was earlier IEC 143 (1992)] 'Series capacitors for power systems' stands redesignated by IEC as mentioned above.

The series comprises the following IEC standards :

IEC Publication	*Title*
IEC 60143-1 (1992)	Series capacitors for power systems — Part 1 : General performance, testing and rating — Safety requirements — Guide for installation
IEC 60143-2 (1994)	Series capacitors for power systems — Part 2 : Protective equipment for series capacitor banks
IEC 60143-3 (1998)	Series capacitors for power systems — Part 3 : Internal fuses

This standard (Part 1) being identical with IEC 60143-1, the other parts of this standard aligning with other parts of IEC 60143 shall be taken up in due course. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

The two digits, three digits and four digits IEC publication No.(s) stand redesignated by prefix 600, 60 and 6 respectively; for example IEC 60-1 and IEC 60-2 stand redesignated as IEC 60060-1 and IEC 60060-2 respectively and IEC 1071-1 stands redesignated as IEC 61071-1.

CROSS REFERENCES

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their respective places are listed along with the latest IEC Publications. Besides giving degree of equivalence, the latest version of IS/IEC has also been referred to in the table as follows:

Pub Referred with Year	*Latest IEC Pub with Year*	*Title of the Latest IEC Pub*	*Corresponding Indian Standard*	*Title of Indian Standard*	*Degree of Equivalence*
IEC 50 (436) : 1990	IEC 60050-436 (1990)	International Electrotechnical Vocabulary — Chapter 436 : Power	IS 1885 (Part 42) : 1993	Electrotechnical vocabulary : Part 42 Power capacitors	Identical
IEC 60-1 : 1989	IEC 60060-1 (1989)	High voltage test techniques — Part 1 : General definitions and test requirements	IS 2071 (Part 1) : 1993	High voltage test techniques : Part 1 General definitions test requirements	do
IEC 60-2 : 1973	IEC 60060-2 (1994)	High voltage test techniques — Part 2 : Measuring systems	IS 2071 (Part 2) : 1974 corresponding to IEC 60060-2 : 1973	High voltage test techniques : Part 2 Test procedures	Not equivalent
IEC 60-3 : 1976	Superseded by IEC 60060-2 (1994)	High voltage test techniques — Part 2 Measuring systems	IS 2071 (Part 3) : 1976 corresponding to IEC 60060-3 : 1976	High voltage test techniques : Part 3 Measuring devices	do
IEC 60-4 : 1977	do	—	No ISS	—	—
IEC 71-1 : 1976	IEC 60071-1 (1993)	Insulation coordination — Part 1 : Definition, principles and rules	IS 2165 (Part 1) : 1977 corresponding to IEC 60071-1 : 1976	Insulation coordination : Part 1 Phase to earth insulation coordination	do
IEC 71-2 : 1976	IEC 60071-2 (1996)	Insulation coordination — Part 2 : Application guide	IS 2165 (Part 2) : 1983 corresponding to IEC 60060-2 : 1976	Insulation coordination : Part 2 Phase to phase insulation coordination principles and rules	do
IEC 71-3 : 1982	Superseded by IEC 60071-1 (1993)	Insulation coordination — Part 1 : Definition, principles and rules	No ISS	—	—
IEC 110 : 1973	IEC 60110-1 (1998) IEC 60110-2 (2000)	Power capacitors for induction heating installation — Part 1 : General	IS 9251 : 1979 corresponding to IEC 60110 : 1973	Capacitors for inductive heat generating plants at frequencies between 40 and 24 000 Hz	Not equivalent

Pub Referred with Year	*Latest IEC Pub with Year*	*Title of the Latest IEC Pub*	*Corresponding Indian Standard*	*Title of Indian Standard*	*Degree of Equivalence*
		Part 2 : Ageing test, destruction test and requirement for disconnecting internal fuses			
IEC 252 : 1993	IEC 60252 (1993)	AC motor capacitors	IS 2993 : 1998	AC motor capacitors	Identical
IEC 549 : 1976	IEC 60549 (1976)	High voltage fuses for the external protec- of shunt power capacitors	IS 9402 : 1980	High voltage fuses for the extenal protection of shunt power capacitors	Not equivalent
IEC 595 : 1977	IEC 60143-3 (1998) Superseded by IEC 60595 : 1977	Series capacitors for power systems — Part 3 : Internal fuses	IS 12677 : 1989 corresponding to IEC 60595 : 1977	Internal fuses for series capacitors	do
IEC 815 : 1986	IEC/TR 60815 (1986)	Guide for the selection of insulators in polluted conditions	IS 13134 : 1992	Guide for selection of insulators in respect of polluted conditions	do
IEC 871-2 : 1987	IEC 60871-2 (1999)	Shunt capacitors for ac power systems having a rated voltage above 1 000 V — Part 2 : Endurance test	IS 13925 (Part 2) : 1994 Standard under revision aligning with IEC 60871-2 (1999)	Shunt capacitors for ac power systems having a rated voltage above 1 000 V : Part 2 Endurance test	Identical to IEC 60871-2 (1987)
IEC 996 : 1989	IEC/TR 60996 (1989)	Method for verifying accuracy of tan-delta measurements applicable to capacitors	IS 13203 : 1991	Method for verifying accuracy of tan-delta measurements	Not equivalent

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

CONTENTS

Page

SECTION 1: GENERAL

Clause

1.1 Scope and object 3
1.2 Normative references 4
1.3 Definitions 5
1.4 Service conditions 8

SECTION 2: QUALITY REQUIREMENTS AND TESTS

2.1 Test requirements 10
2.2 Classification of tests 11
2.3 Capacitance measurement (routine test) 12
2.4 Capacitor loss measurement (routine test) 13
2.5 Voltage test between terminals (routine test) 14
2.6 A.C. voltage test between terminals and container (routine test) 14
2.7 Test on internal discharge device (routine test) 14
2.8 Sealing test (routine test) 14
2.9 Thermal stability test (type test) 15
2.10 A.C. voltage test between terminals and container (type test) 16
2.11 Lightning impulse voltage test between terminals and container (type test) 17
2.12 Cold duty test (type test) 18
2.13 Discharge current test (type test) 19

SECTION 3: INSULATION LEVEL

3.1 Test voltages 20
3.2 Creepage distance 22

Clause

SECTION 4: OVERLOADS AND OVERVOLTAGES

4.1 Working currents 24

4.2 Transient overvoltages 25

SECTION 5: SAFETY REQUIREMENTS

5.1 Discharge device 25

5.2 Container connection 25

5.3 Protection of the environment 26

5.4 Other safety requirements 26

SECTION 6: MARKINGS

6.1 Markings of the unit 26

6.2 Markings of the bank 27

SECTION 7: GUIDE FOR SELECTION OF RATINGS, AND FOR INSTALLATION AND OPERATION

7.1 General 28

7.2 Choice of rated current and voltage ratings 28

7.3 Capacitance 30

7.4 Operating temperature 30

7.5 Special conditions 31

7.6 Protective and switching devices 31

7.7 Choice of insulation level 35

7.8 Disturbing phenomena 36

ANNEXE

A Test requirements and application guide for external fuses and units to be externally fused 38

B Some examples of connection diagrams of phase banks or segments 42

C Precautions to be taken to avoid pollution of the environment by polychlorinated biphenyls 43

D Bibliography 44

Indian Standard

SERIES CAPACITORS FOR POWER SYSTEMS

PART 1 GENERAL PERFORMANCE, TESTING AND RATING — SAFETY REQUIREMENTS — GUIDE FOR INSTALLATION

(First Revision)

SECTION 1: GENERAL

1.1 Scope and object

This International Standard applies both to capacitor units and capacitor banks intended to be used connected in series with an a.c. transmission or distribution line or circuit forming part of an a.c. power system having a frequency of 15 Hz to 60 Hz.

The series capacitor units and banks are usually intended for high voltage power systems. This standard is applicable to the complete voltage range.

NOTES

1 Additional requirements for capacitors to be protected by internal fuses as well as the requirements for internal fuses are found in IEC 595.

2 Additional requirements for capacitors to be protected by external fuses as well as the requirements for external fuses are found in annex A.

3 This standard does not apply to capacitors of the self-healing metallized dielectric type.

4 The following capacitors, even if connected in series with a circuit, are excluded from this standard:

- capacitors for inductive heat-generating plants (IEC 110);
- capacitors for motor applications and the like (IEC 252);
- capacitors to be used in power electronics circuits (IEC 1071);
- capacitors for discharge lamps (IEC 566).

5 A separate standard for series capacitor accessories (spark-gaps, non-linear resistors, discharge reactors, damping resistors, breakers, etc.) is under consideration.

6 Standard type of accessories such as insulators, switches, instrument transformers, external fuses, etc., shall comply with the pertinent IEC standard.

The object of this standard is

- to formulate uniform rules regarding performance, testing and rating;
- to formulate specific safety rules;
- to provide a guide for installation and operation.

1.2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(436): 1990, *International Electrotechnical Vocabulary (IEV) – Chapter 436: Power capacitors.*

IEC 60, *High-voltage test techniques.*

IEC 60-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements.*

IEC 60-2: 1973, *High-voltage test techniques – Part 2: Test procedures.*

IEC 60-3: 1976, *High-voltage test techniques – Part 3: Measuring devices.*

IEC 60-4: 1977, *High-voltage test techniques – Part 4: Application guide for measuring devices.*

IEC 71, *Insulation co-ordination.*

IEC 71-1: 1976, *Insulation co-ordination – Part 1: Terms, definitions, principles and rules.*

IEC 71-2: 1976, *Insulation co-ordination – Part 2: Application guide.*

IEC 71-3: 1982, IEC 71-1: 1976, *Insulation co-ordination – Part 3: Phase-to-phase insulation co-ordination. Principles, rules and application guide.*

IEC 549: 1976, *High-voltage fuses for the external protection of shunt power capacitors.*

IEC 595: 1977, *Internal fuses for series capacitors.*

IEC 816: 1986, *Guide for the selection of insulators in respect of polluted conditions.*

IEC 871-2: 1987, *Shunt capacitors for a.c. power systems having a rated voltage above 660 V. Part 2: Endurance testing.*

IEC 996: 1989, *Method for verifying accuracy of tan delta measurements applicable to capacitors.*

1.3 Definitions

For the purposes of this International Standard, the following definitions apply:

1.3.1 **capacitor element (or element)**: A device consisting essentially of two electrodes separated by a dielectric. [IEV 436-01-03 modified]

1.3.2 **capacitor unit (or unit)**: An assembly of one or more capacitor elements in the same container with terminals brought out. [IEV 436-01-04 modified]

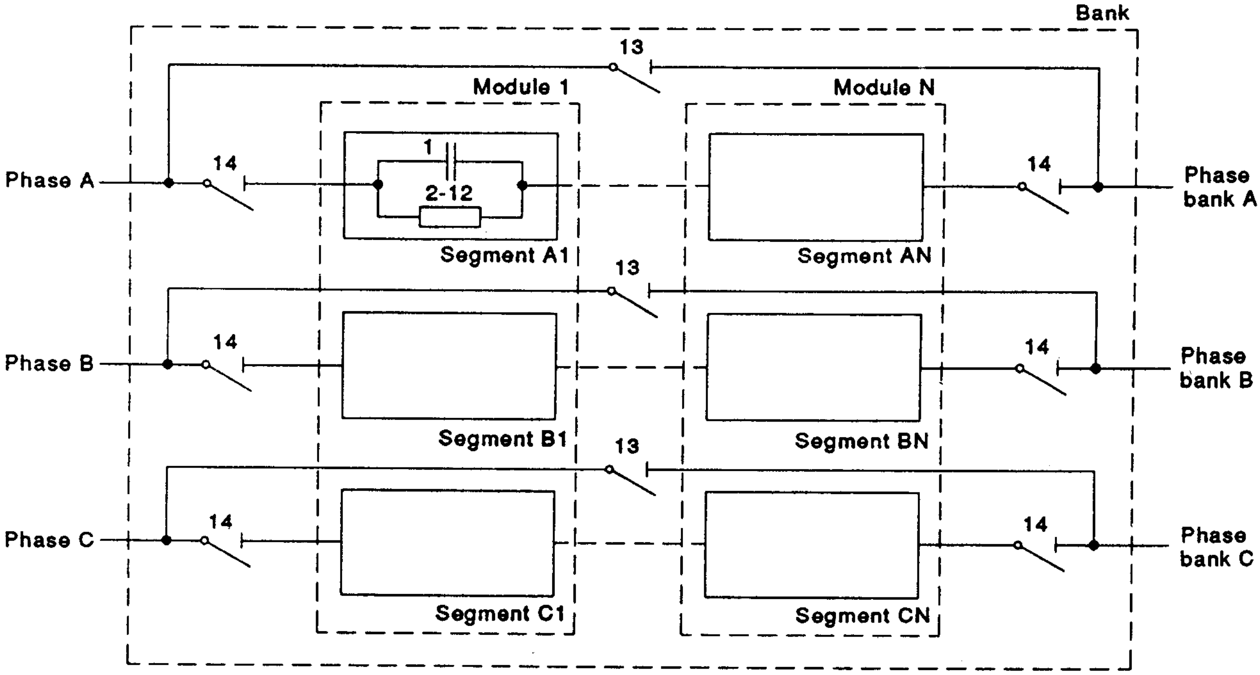
1.3.3 **series capacitor phase bank (or phase bank)**: An assembly of capacitor units connected in one phase so as to act together, the protection system(s) for these capacitors, etc. (see figure 1).

1.3.4 **segment (of a series capacitor)**: Where the phase bank is divided into several series-connected parts of which each part contains its own assembly of capacitor units and protection system(s) each such complete part is called segment (see figure 1).

1.3.5 **series capacitor bank (or bank)**: The three-phase banks operated in common (see figure 1). [IEV 436-01-06 modified]

1.3.6 **module (of a series capacitor)**: A switchable step of a series capacitor consisting of identical segments in each phase (see figure 1), which furthermore also are equipped with provisions for a common operation of the by-pass device at each of these segments.

NOTE - If maintenance is required on the segment(s) of a by-passed module when the remaining module(s) of the series capacitor remains in operation also series disconnecting devices (and other personal safety requirements) are needed for the segments.



1 = Assembly of capacitor units

2-12 = Main protective equipment

13 = By-pass disconnector

14 = Series disconnector

(See also figure B3 of annex B)

Figure 1 – Series capacitor bank definitions

1.3.7 **capacitor**: In this standard, the word "capacitor" is used when it is not necessary to lay particular stress upon the different meanings of the words capacitor unit, segment or phase bank.

1.3.8 **capacitor installation**: A series capacitor bank and its accessories. [IEV 436-01-07 modified]

1.3.9 **overvoltage protector (of a series capacitor)**: A quick-acting device which limits the instantaneous voltage across the capacitor to a permissible value when that value would otherwise be exceeded as a result of a circuit fault or other abnormal network conditions. [IEV 436-03-14 modified]

1.3.10 **discharge device (of a capacitor)**: A device connected across the terminals of the capacitor or built into the capacitor unit, capable of reducing the residual voltage across the capacitor effectively to zero after the capacitor has been disconnected from the supply. Further requirements on the size of the discharge device are found in clause 5.1. [IEV 436-03-15 modified]

1.3.11 **internal fuse (of a capacitor)**: A fuse connected inside a capacitor unit, in series with an element or a group of elements. [IEV 436-03-16]

1.3.12 **external fuse (of a capacitor)**: A fuse connected in series with a capacitor unit or with a group of parallel units.

1.3.13 **line terminals:** The terminals to be connected to the lines. [IEV 436-03-01 modified]

1.3.14 **rated capacitance (of a capacitor)** (C_N): The capacitance value for which the capacitor has been designed. [IEV 436-01-12 modified]

1.3.15 **rated current (of a capacitor)** (I_N): The r.m.s. value of the alternating current for which the capacitor has been designed. [IEV 436-01-13]

NOTE - Due consideration should be given to the time profile of the line current (7.2.1).

1.3.16 **rated frequency (of a capacitor)** (f_N): The frequency of the system in which the capacitor is intended to be used. [IEV 436-01-14 modified]

1.3.17 **rated voltage (of a capacitor)** (U_N): The r.m.s. value of the voltage between the terminals, derived from rated capacitance, rated current and rated frequency. [IEV 436-01-15 modified]

1.3.18 **rated output (of a capacitor)** (Q_N): The reactive power derived from rated capacitance, rated current and rated frequency. [IEV 436-01-16 modified]

1.3.19 **capacitor losses**: The active power dissipated by a capacitor. [IEV 436-04-10 modified]

NOTES

1 All loss-producing components shall be included:

- for a unit, losses from the dielectric, internal fuses, discharge device(s), internal connections, etc.;
- for a bank, losses from the units, external fuses, busbars, discharge and damping reactors, etc.

Losses may also be generated by auxiliary power for heating of breakers, cubicles, etc.

2 The capacitor losses may be recalculated as an equivalent series resistance to the capacitor.

3 When evaluating the losses, it is recommended either to use the loss value at the average ambient air temperature or to use the losses at some different ambient air temperatures and calculate their mean value. Series capacitors usually have an average output well below rated, which should be taken into account.

1.3.20 **tangent of loss angle (of a capacitor)** (tan δ): The ratio between the equivalent series resistance and the capacitive reactance of a capacitor at specified sinusoidal alternating voltage and frequency.

NOTE - Tangent of loss angle can also be expressed as the capacitor losses divided by the reactive power of the capacitor.

1.3.21 **limiting voltage** (U_{lim}): The maximum instantaneous voltage occurring between capacitor terminals immediately before or during operation of the overvoltage protector, divided by $\sqrt{2}$.

1.3.22 **highest voltage of a three-phase system**: The highest r.m.s. phase-to-phase voltage which occurs under normal operating conditions at any time and at any point of the system. It excludes voltage transients (such as those due to system switching) and temporary voltage variations due to abnormal system conditions (such as due to faults or sudden disconnection of large loads).

1.3.23 **highest voltage for equipment** (U_m): The highest r.m.s. phase-to-phase voltage for which the equipment is designed as regards its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards. This voltage is the maximum value of the highest voltage of the system for which the equipment may be used.

1.3.24 **insulation level** (U_i): The non-simultaneous combination of test voltages (power-frequency or switching impulse, and lightning impulse) which characterizes the insulation of the capacitor with regard to its capability of withstanding the electric stresses between terminals and earth, between phases and between terminals and metalwork not at earth potential.

1.3.25 **ambient air temperature**: The temperature of air at the proposed location of the capacitor.

1.3.26 **cooling air temperature**: The temperature of cooling air measured at the hottest position in the phase bank, under steady-state conditions, midway between two units. If only one unit is involved, it is the temperature measured at a point approximately 0,1 m away from the capacitor container and at two-thirds of the height from its base.

1.3.27 **steady-state condition**: Thermal equilibrium attained by the capacitor at constant output and at constant ambient air temperature.

1.3.28 **residual voltage**: The voltage remaining between terminals of a capacitor at a given time following disconnection of the supply.

1.4 Service conditions

1.4.1 *Normal service conditions*

This standard gives requirements for capacitors to be used in the following conditions.

1.4.1.1 *Altitude*

Not exceeding 1 000 m.

1.4.1.2 *Ambient air temperature categories*

Capacitors are classified in temperature categories, each category being specified by one number followed by one letter. The number represents the lowest ambient air temperature at which the capacitor may operate. The letter represents the upper limit of temperature variation range, having the maximum value specified in table 1.

Table 1 – Letter symbols for upper limit of temperature range

Symbol	Ambient air temperature °C		
	Max.	Highest mean over any period of 24 h	Highest mean over any period of 1 year
A	40	30	20
B	45	35	25
C	50	40	30
D	55	45	35

The temperature categories cover a total temperature range from –50 °C to +55 °C. The lowest ambient air temperature at which the capacitor may be operated should be chosen from the five preferred values +5 °C, -5 °C, -25 °C, -40 °C, -50 °C.

Any combination of minimum and maximum values can be chosen for the standard temperature category of a capacitor, for example -40/A or -5/C.

Table 1 is based on service conditions in which the capacitor does not influence the ambient air temperature (e.g. outdoor installations). If the capacitor influences the air temperature, the ventilation and/or choice of capacitor shall be such that the limits of table 1 are maintained. The cooling air temperatures in such installations shall not exceed the temperature limits of table 1 by more than 5 °C.

NOTE - The temperature values according to table 1 can be found in the meteorological temperature tables covering the installation site.

1.4.2 *Unusual service conditions*

Unless otherwise agreed between the manufacturer and purchaser, this standard does not apply to capacitors, the service conditions of which are incompatible with the requirements of this standard.

SECTION 2: QUALITY REQUIREMENTS AND TESTS

2.1 Test requirements

2.1.1 *General*

This section gives the test requirements for capacitor units.

Supporting insulators, switches, instrument transformers, external fuses, etc., shall be in accordance with the pertinent IEC standard.

2.1.2 *Test conditions*

Unless otherwise specified for a particular test or measurement, the temperature of the capacitor dielectric shall be in the range +5 °C to +35 °C. When a correction has to be applied, the reference temperature to be used is +20 °C, unless otherwise agreed between the manufacturer and the purchaser. It may be assumed that the dielectric temperature of the capacitor unit is the same as the ambient air temperature, provided that the capacitor has been left in an unenergized state in a constant ambient air temperature for an adequate period.

The a.c. tests and measurements shall be carried out at a frequency of 50 Hz or 60 Hz irrespective of the rated frequency of the capacitor unless otherwise specified.

2.1.3 *Determination of test voltages between terminals*

The value of a test voltage (U_t) between terminals depends on the type of the overvoltage protector and its limiting voltage U_{lim} (see 7.6.2). Table 2 gives the test voltage factors to be multiplied by U_{lim}.

NOTE - If the repetitive function of the arc (protector types L and N2) takes place above $0{,}8\sqrt{2}\,U_{\text{lim}}$, the factors 2,0, 1,4 and 1,8 should be increased linearly.

Table 2 – Test voltage multiplying factors

Protector type	D.C. test (see 2.5.1)	A.C. test (see 2.5.2)	Damped discharge test (see clause 2.13)
K and N1	1,7	1,2	1,6
L and N2	2,0	1,4	1,8
M	1,9	1,3	1,7
No protector	1,9	1,3	1,7

2.2 Classification of tests

2.2.1 *Routine tests*

a) Capacitance measurement (clause 2.3)
b) Capacitor loss measurement (clause 2.4)
c) Voltage test between terminals (clause 2.5)
d) A.C. voltage test between terminals and container (clause 2.6)
e) Test on internal discharge device (clause 2.7)
f) Sealing test (clause 2.8)

The test sequence is not necessarily that indicated above.

The routine tests shall be carried out by the manufacturer on every capacitor unit before delivery.

NOTE - A short-circuit discharge test is under consideration.

2.2.2 *Type tests*

a) Thermal stability test (clause 2.9)
b) A.C. voltage test between terminals and container (clause 2.10)
c) Lightning impulse voltage test between terminals and container (clause 2.11)
d) Cold duty test (clause 2.12)
e) Discharge current test (clause 2.13)

The type tests are carried out in order to ensure that the capacitor unit complies with the contractual characteristics and with the operational requirements as specified in this standard.

The type tests shall be made upon capacitor unit(s) of identical design with the units under contract or on capacitor unit(s) the design and processing of which do not differ from the contractual units in any way that might influence the properties to be checked by the type test.

It is not essential that all type tests are carried out on the same capacitor unit.

The above list of type tests does not indicate any test sequence.

Unless otherwise specified, every capacitor sample to which a type test will be applied shall have first withstood satisfactorily the application of all the routine tests.

2.2.3 *Acceptance tests*

The routine and/or type tests, or some of them, may be repeated by the manufacturer in connection with any contract by agreement with the purchaser.

The number of samples to be subjected to such tests, the acceptance criteria, and the test reports shall be stated in the contract.

NOTE - If agreed between the manufacturer and purchaser, withstand voltage tests on banks, in order to verify the insulation levels, may be carried out between terminals and earth, between phases, and between terminals and metalwork not at earth potential.

2.2.4 *Endurance test* (special test)

The endurance test will be carried out only after a contractual agreement between the manufacturer and purchaser.

Endurance test parameters and requirements for series capacitors are under consideration. Meanwhile the endurance test can be made according to IEC 871-2. However, other voltage levels may apply (see clause 2.12).

The endurance test is a test on elements (their dielectric design and composition), and on the manufacturing process of these elements when assembled in a capacitor unit. An endurance test, which is both time consuming and expensive, covers a range of capacitor designs.

It is recommended that the manufacturer should furnish an endurance test report covering the unit design under contract (see IEC 871-2 for "identical designs").

2.3 **Capacitance measurement** (routine test)

2.3.1 *Measuring procedure*

The capacitance shall be measured at 0,9 to 1,1 times the rated voltage, using a method that excludes errors due to harmonics. Measurement at another voltage is permitted, provided that an appropriate correction factor is agreed upon between the manufacturer and purchaser.

The accuracy of the measuring method shall be such that the tolerances according to 2.3.2 can be kept. The repeatability of the measuring method shall be such that a punctured element or an operated internal fuse can be detected.

The final capacitance measurement shall be carried out after the voltage test (clause 2.5). In order to reveal any change in capacitance e.g. due to puncture of an element, or failure of an internal fuse, a preliminary capacitance measurement shall be made before the other voltage routine tests. This preliminary measurement shall be performed with a voltage not higher than 0,15 U_N.

The manufacturer shall, on agreement, provide curves or tables showing:

- the capacitance in steady-state condition at rated output as a function of ambient air temperature within the temperature category;
- the capacitance as a function of the dielectric temperature within the temperature category.

2.3.2 *Capacitance tolerance*

The tolerances refer to capacitance values measured at 0,9 to 1,1 times the rated voltage under the conditions of 2.3.1.

The capacitance at reference temperature shall not differ from the rated capacitance by more than:

- ±7,5 % for units;
- ±5,0 % for banks with a rating less than 30 Mvar;
- ±3,0 % for banks with a rating of 30 Mvar or more.

Furthermore, the capacitance shall not differ by more than:

- 3,0 % between any two phase banks or any two segments within the same module with a bank rating less than 30 Mvar;
- 1,0 % between any two phase banks or any two segments within the same module with a bank rating of 30 Mvar or more.

Closer tolerances might be required for capacitors in more critical applications (see 7.3.1).

NOTE - Units having internal fuses, and within the capacitance tolerances in spite of operated fuse(s), may be delivered only after contractual agreement between the manufacturer and purchaser. In such a case, the electrical routine tests shall be repeated after operation of the fuse(s).

2.4 **Capacitor loss measurement** (routine test)

2.4.1 *Measuring procedure*

The capacitor losses (or tan δ) shall be measured at 0,9 to 1,1 times rated voltage using a method that excludes errors due to harmonics.

NOTE - The measuring equipment should be calibrated according to IEC 996 or to another method that will give the same or an approved accuracy.

2.4.2 *Loss requirements*

The capacitor losses refer to values measured under the conditions of 2.4.1.

The requirements regarding capacitor losses may be agreed upon between the manufacturer and purchaser.

The manufacturer should, by agreement, provide curves or tables showing the stabilized capacitor losses (or tan δ) under steady-state condition at rated output as a function of ambient air temperature within the temperature category.

NOTE - The tangent of loss angle of most low-loss dielectrics decreases considerably during the first hours of initial energization. This decrease is not correlated to the tan δ variation with temperature. The initial tan δ decrease may vary also between identical units manufactured simultaneously. The final "stabilized" values are, however, usually within close limits.

2.5 Voltage test between terminals (routine test)

The capacitor units shall be subjected to either test 2.5.1 or test 2.5.2. In the absence of an agreement, the choice is left to the manufacturer. During the test, neither puncture nor flashover shall occur. See, however, note in 2.3.2.

2.5.1 *D.C. test*

The test voltage value shall be in accordance with table 2, but not less than 4,3 U_N. The duration of the test shall be 10 s.

NOTE - If the capacitors are to be retested after delivery, a voltage of 75 % of U_t is recommended for the re-test.

2.5.2 *A.C. test*

The a.c. test shall be carried out with a substantially sinusoidal voltage having the value in accordance with table 2, but not less than 2,15 U_N. The duration of the test shall be 10 s.

NOTE - See note in 2.5.1

2.6 A.C. voltage test between terminals and container (routine test)

Units having both terminals insulated from the container shall be subjected for 10 s to a test voltage applied between the terminals (joined together) and the container. The value of the test voltage shall be chosen according to clause 3.1.

During the test, neither puncture nor flashover shall occur.

The test shall be performed even if one of the terminals in service is intended to be connected to the container.

Units having one terminal permanently connected to the container shall not be subject to this test.

2.7 Test on internal discharge device (routine test)

The resistance of the internal discharge device, if any, shall be checked by a measurement. The method may be selected by the manufacturer.

The test shall be made after the voltage test of clause 2.5.

2.8 Sealing test (routine test)

The unit (in non-painted state) shall be exposed to a test that will effectively detect any leak of the container and bushing(s). The test procedure is left to the manufacturer, who shall describe the test method concerned.

If no procedure is stated by the manufacturer the following test procedure shall apply:

> Unenergized capacitor units shall be heated throughout so that, for at least 2 h, all parts reach a temperature not less than 20 °C above the maximum value in table 1. No leakage shall occur. It is recommended that a suitable leakage indicator should be used.

2.9 Thermal stability test (type test)

2.9.1 *General*

This test is intended to:

- determine the thermal stability of the capacitor under overload conditions;
- condition the capacitor in order to obtain a stable and final tan δ value (see note in 2.4.2).

2.9.2 *Measuring procedure*

The capacitor unit subjected to the test shall be placed between two barrier units with the same rating, and they shall be energized at the same voltage as the test capacitor. The barrier units shall have almost similar container dimensions as the unit under test. Alternatively, two dummy capacitors both containing resistors may be used as barrier units. Dissipation in the resistors shall be adjusted to such a value that the case temperatures of the dummy capacitors are equal to or higher than those of the test capacitor. The temperature of the units shall be measured at "equal" spots which must not be exposed to direct heat radiation from another unit. The separation between the units shall be equal to or less than the normal spacing. The assembly shall be placed in still air in a heated enclosure in the most unfavourable thermal position according to the manufacturer's instructions for mounting on site. The ambient air temperature shall be maintained at the appropriate value shown in table 3 (tolerance ±2 °C). It shall be checked by means of a thermometer having a thermal time constant of approximately 1 h. This thermometer shall be shielded so that it is exposed to the minimum possible thermal radiation from the energized sample and the energized barrier units.

Table 3 – Ambient air temperature in thermal stability test

Symbol	Temperature °C
A	40
B	45
C	50
D	55

The test capacitor shall be subjected to an a.c. voltage of substantially sinusoidal form for a period of at least 48 h. The magnitude of the voltage shall be kept constant throughout the test. Its value is derived from the measured capacitance (see 2.3.1) to give a calculated output of the capacitor equal to 1,5 times the rated output. The test value 1,5 Q_N is related to the 8 h overload current 1,1 I_N according to clause 4.1. If this 8 h overcurrent has been increased, the factor 1,5 shall be increased in square.

During the last six hours, the temperature of the container shall be measured at least four times. Throughout this period of 6 h, the temperature rise shall not increase more than 1 K. Should a greater change be observed, the test may be continued until the above requirement is met for four consecutive measurements during a subsequent 6 h period.

Before and after the test, the capacitance shall be measured (see 2.3.1) within the temperature range according to 2.1.2 and the two measurements shall be corrected to the same dielectric temperature. The difference between the two measurements shall be less than an amount corresponding to puncture of an element or operation of an internal fuse. When interpreting the results of the measurements, the following factors shall be taken into account:

- the reproducibility of the measurements;
- the fact that internal change in dielectric may cause a small change of capacitance, without puncture of any element or operation of an internal fuse having occurred.

NOTES

1 When checking whether the temperature conditions are satisfactory, voltage fluctuation, frequency and ambient air temperature during the test shall be taken into account. For this reason, it is advisable to plot these parameters and the temperature rise of the container as a function of time.

2 Units intended for 60 Hz installation may be tested with 50 Hz and vice versa provided that the specified output is applied. For units rated below 50 Hz the test conditions shall be agreed between the manufacturer and purchaser.

2.9.3 *Capacitor loss measurement*

The capacitor losses (or tan δ) shall be measured at the end of the thermal stability test. The measuring voltage shall be that of the thermal stability test. Otherwise 2.4.1 applies.

The value of tan δ measured shall not exceed the value declared by the manufacturer or the value agreed upon between the manufacturer and purchaser.

2.10 A.C. voltage test between terminals and container (type test)

Units having both terminals insulated from the container shall be subjected to a test voltage applied for 1 min between the terminals joined together and the container. The value of the test voltage shall be chosen according to clause 3.1. Test on units having one terminal permanently connected to the container shall be limited to the bushing and container (without elements).

The test is dry for units to be used indoors, and for units to be used outdoors it is performed in artificial rain (IEC 60). The position of the bushings when subject to a test in the artificial rain shall correspond to their position in service.

During the test, neither puncture nor flashover shall occur.

NOTE - Units intended for outdoor installation may be subjected to a dry test only if the manufacturer can supply a separate type test report showing that the bushings will withstand the wet test voltage for 1 min. The position of the bushing in this separate type test shall correspond to the service position.

2.11 Lightning impulse voltage test between terminals and container (type test)

2.11.1 *General*

This test is applicable only to units according to the following requirements:

- units having all terminals insulated from the container shall be tested in accordance with 2.11.2;
- units having one terminal connected to the container shall - on a model unit - be tested in accordance with 2.11.3.

For units with containers insulated from earth, a lightning impulse test voltage shall be chosen, which amplitude corresponds to the a.c. test voltage according to clause 3.1.

The lightning impulse test shall be made in accordance with IEC 60 but with a wave-shape of (1,2 to 5)/50 µs having a crest value corresponding to the insulation level of the unit according to clause 3.1.

The absence of failure or partial puncture during the test shall be verified by recording the voltage and by checking the wave shape.

2.11.2 *Test on standard unit*

Fifteen impulses of positive polarity followed by 15 impulses of negative polarity shall be applied between the bushings joined together and the container. After the change of polarity it is permissible to apply some impulses of lower amplitude before the application of the negative impulses.

The capacitor is considered to have passed the test if:

- no puncture has occurred;
- not more than two flashovers have occurred at each polarity;
- the wave-shape has revealed no irregularities, or if so, the wave shape recorded at a reduced voltage (50 % to 70 % of the test voltage) does not differ significantly from that recorded at test voltage.

Alternatively the unit may be tested according to 2.11.3.

2.11.3 *Test on model unit and standard unit*

The model unit shall be equipped with bushing(s), shall have the internal bushing connection wire provided with its standard insulation, shall be filled with impregnant but shall contain no elements. The internal bushing connection wire may be either bent in a U-shape between the bushings or be fitted with a relieving device for the electrical stress.

The model unit shall be tested and accepted according to 2.11.2.

The standard unit shall be subjected to three positive impulses applied between the bushings joined together and the container. The acceptance criteria of 2.11.2 are applicable except that no flashover is permitted.

The test on the model unit is intended to verify the external insulation and the test on the standard unit is intended to verify the internal insulation.

2.12 **Cold duty test** (type test)

The voltages applied during this test shall be substantially sinusoidal. The test circuit shall be suitably damped to reduce overvoltages due to transients.

The initial dielectric temperature of the test unit prior to the voltage application shall be the lowest temperature of the temperature category.

For applications where the overload conditions following system disturbances are unknown, the following test shall be applied.

The unit shall within 10 min after being removed from the refrigerator be exposed to 1,5 U_N (between terminals), and within 30 s thereafter, an overvoltage of 1,1 U_{lim} (but at least 2,25 U_N) shall be applied without any voltage interruption for a period of five to 10 cycles after which 1,5 U_N is maintained again without any voltage interruption (figure 2, page 19). After an interval of 1,5 to 2 min at 1,5 U_N, another equal overvoltage period shall be applied, and so on until the following number of power frequency overvoltage periods of 1,1 U_{lim} have been applied (see figure 2, page 19):

- 50 overvoltage cycles for protector types K and N1;
- 100 overvoltage cycles for protector types L, M and N2.

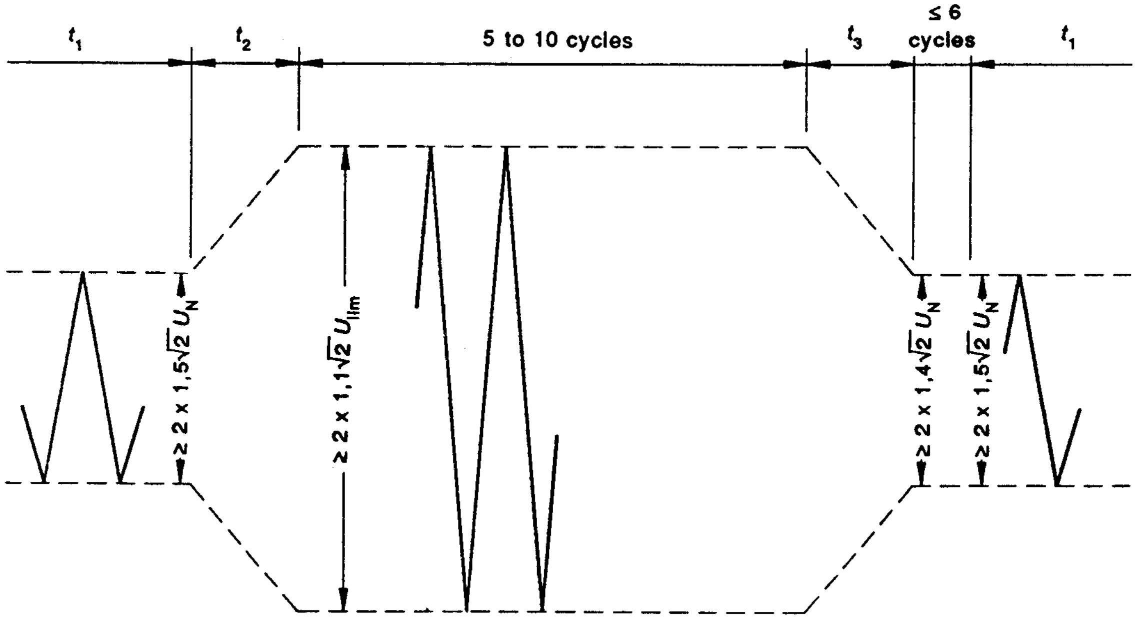
In the case of no overvoltage protector, each single overvoltage period shall be equal to or longer than the duration of the fault voltage U_{lim} before the fault is switched off or the capacitor by-passed. The capacitor shall be exposed to five overvoltage periods of this duration.

After the last overvoltage period, a voltage of 1,5 U_N shall be maintained for a time of 30 min.

When overload conditions are known, the voltage versus time profile between the overvoltage test periods of 1,1 U_{lim} and the subsequent overvoltage test level(s) (i.e., 1,5 U_N) may be changed as agreed between purchaser and manufacturer. These revised test conditions should be based on maximum working currents (clause 4.1) and overload conditions following system disturbances (see 7.2.1 and figure 3, page 29).

Before and after the test, the capacitance shall be measured according to 2.3.1 and the two measurements shall be corrected to the same dielectric temperature (see 2.1.2). There shall be no significant change of capacitance for these measurements and in any case it shall be less than the change corresponding to puncture of an element or to operation of an internal fuse. When interpreting the results of the measurements, the factors stated in 2.9.2 shall be taken into account.

The cold duty test may be performed on either a standard unit or on a special unit having the characteristics described in IEC 871-2.



The time t_1 is the interval of 1,5 min to 2 min between two consecutive overvoltage applications. The times t_2 and t_3 depend on the test circuit parameters and should be as short as possible.

Figure 2 – Time and amplitude limits for an overvoltage period

2.13 **Discharge current test** (type test)

The capacitor unit shall be charged to a d.c. voltage of $\sqrt{2}\ U_{\mathrm{lim}}$ (but not less than 2,5 U_N) and then discharged once through a circuit having an impedance as low as possible.

The same unit shall then be charged to a d.c. voltage in accordance with table 2 and discharged through a circuit which satisfies the following conditions:

- the peak value of the discharge current shall be not less than 120 times the rated (r.m.s.) current of the capacitor unit;

- the damping of the discharge current shall be at least 10 % less than the contractual damping (see 7.6.3).

This discharge shall be repeated 10 times at intervals of less than 20 s. Within 10 min after the last discharge, the unit shall be subjected to a voltage test between terminals according to clause 2.5.

Before and after the test, the capacitance shall be measured according to 2.3.1 and the two measurements shall be corrected to the same dielectric temperature (see 2.1.2). There shall be no significant change of capacitance at these measurements and in any case it shall be less than the change corresponding to puncture of an element or to operation of an internal fuse. When interpreting the results of the measurements, the factors stated in 2.9.2 shall be taken into account.

NOTES

1 When the discharge current following operation of the overvoltage protector is substantially different from 100 times the rated current in the case of overvoltage protectors type K, M or N1, or 50 times the rated current in the case of overvoltage protectors type L or N2 (see 7.6.2), the discharge current specified for the test shall be changed to 1,2 times the first peak of the discharge current for the protectors Type K, M and N1 and to 2,4 times the same to the protectors Type L and N2.

2 If the capacitor in service is expected to be subjected to frequent discharges, the number of damped discharges in the above test may, by agreement, be increased to 20.

3 The undamped discharge is intended to prove that the units can withstand the stresses occurring at a flashover which by-passes the damping circuit.

SECTION 3: INSULATION LEVEL

3.1 Test voltages

3.1.1 *Standard values*

The test voltages of the capacitor units and of the capacitor installation shall be chosen from the standard values prescribed by IEC 71 (IEC 71-1, 71-2 and 71-3).

The standardized values of the highest voltage for equipment are divided into three ranges:

Range A: Voltage less than 52 kV. The values of IEC 71 are supplemented by two values (1,2 kV and 2,4 kV) of the highest voltage for equipment and are given in table 4-A (current practice in most European and several other countries). The choice between the values of list 1 or list 2 may be made taking into account the information given in IEC 71. Values based on current practice in some North American and other countries are given in table 4-B.

Range B: From 52 kV to less than 300 kV. The values of IEC 71 are given in table 5. The table associates one or more recommended insulation levels with each standard value of the highest voltage for equipment. Intermediate values shall not be employed. Several insulation levels may exist in the same system appropriate to installations situated in different locations or to various equipment situated in the same installation. For selection of the insulation level in relation to the particular conditions of the installation, see IEC 71.

Range C: 300 kV and above. The values of IEC 71 are given in table 6. The table associates two or more recommended insulation levels with each standard value of the highest voltage for equipment. Intermediate values shall not be employed. Several insulation levels may exist in the same system appropriate to installations situated in different locations or to various equipment situated in the same installation. For selection of the insulation given by the level in relation to the particular conditions of the installation, see IEC Standard 71.

The purchaser shall specify which of the alternative test voltages of tables 4 to 6 shall be applied.

3.1.2 *Test voltages of capacitor units*

3.1.2.1 *Units with full insulation to container*

The units having container connected to earth shall have an insulation level according to table 4-A or table 4-B.

3.1.2.2 *Units with container insulated from earth*

This sub-clause applies to units mounted on insulated racks.

The power-frequency test voltage of the insulation to the container shall be calculated according to the following formula:

$$U_t = 1{,}2\, n\, U_{\text{lim}} \qquad (1)$$

with a minimum of 2,15 $n\,U_N$, where U_t is the power frequency test voltage, U_{lim} the limiting voltage of the capacitor unit, U_N the rated voltage of the capacitor unit and n the number of units in series relative to the metal rack to which the containers are connected (e.g., if six units are series-connected in one rack with the centre point connected to the rack, $n = 3$).

3.1.3 *Insulation to earth and between phase banks*

The test voltages shall be chosen from the standard values in accordance with 3.1.1.

3.1.4 *Insulation across phase bank*

Each insulation across parts of a phase bank shall have the test voltages determined according to formula (1) in 3.1.2.2. However, in this case n corresponds to the number of units which span across this insulation.

NOTE - For the damping circuit and insulation connected in parallel with it, the power frequency test voltage shall be chosen to $1{,}2/\sqrt{2}$ times the instantaneous voltage appearing across the damping circuit when the overvoltage protector operates (clauses 7.6 and 7.7).

3.2 Creepage distance

The recommendations given in IEC 815 apply. The purchaser shall specify which one of the pollution levels or the minimum specific creepage distance shall be applicable.

The specific creepage distance values given in IEC 815 are based on the highest voltage for equipment (see 1.3.23).

a) Creepage distances to earth and between phases:

The requirements of IEC 815 shall be used.

b) Creepage distances within a phase bank or segment:

The rated voltage across each individual creepage distance shall be multiplied by $1,2\sqrt{3}$. The obtained value forms an "equivalent" highest voltage for equipment which shall be multiplied with the selected specific creepage distance value to obtain the required minimum creepage distance. The factor 1,2 allows for the overvoltages caused by the permissible overcurrents according to clause 4.1. If any of the overcurrents of clause 4.1 has been increased, the factor 1,2 shall be increased linearly to the overcurrent of clause 4.1 that has been increased most.

Those insulators which under normal operating conditions are exposed to a very low voltage but which are subjected to a high voltage during operation of the overvoltage protector shall be selected by the test voltage requirement alone.

Table 4-A – Standard phase-to-earth and phase-to-phase insulation levels for U_m < 52 kV - Series I (based on current practice in most European and several other countries)

Highest voltage for equipment U_m (r.m.s.)	Rated lightning impulse withstand voltage (peak)		Rated short duration power-frequency withstand voltage (r.m.s.)
	Liste 1	Liste 2	
kV	kV	kV	kV
1,2	–	25	6
2,4	–	35	8
3,6	20	40	10
7,2	40	60	20
12	60	75	28
17,5	75	95	38
24	95	125	50
36	145	170	70

Table 4-B – Standard phase-to-earth and phase-to-phase insulation levels for U_m < 52 kV - Series II (based on current practice in some North American and other countries)

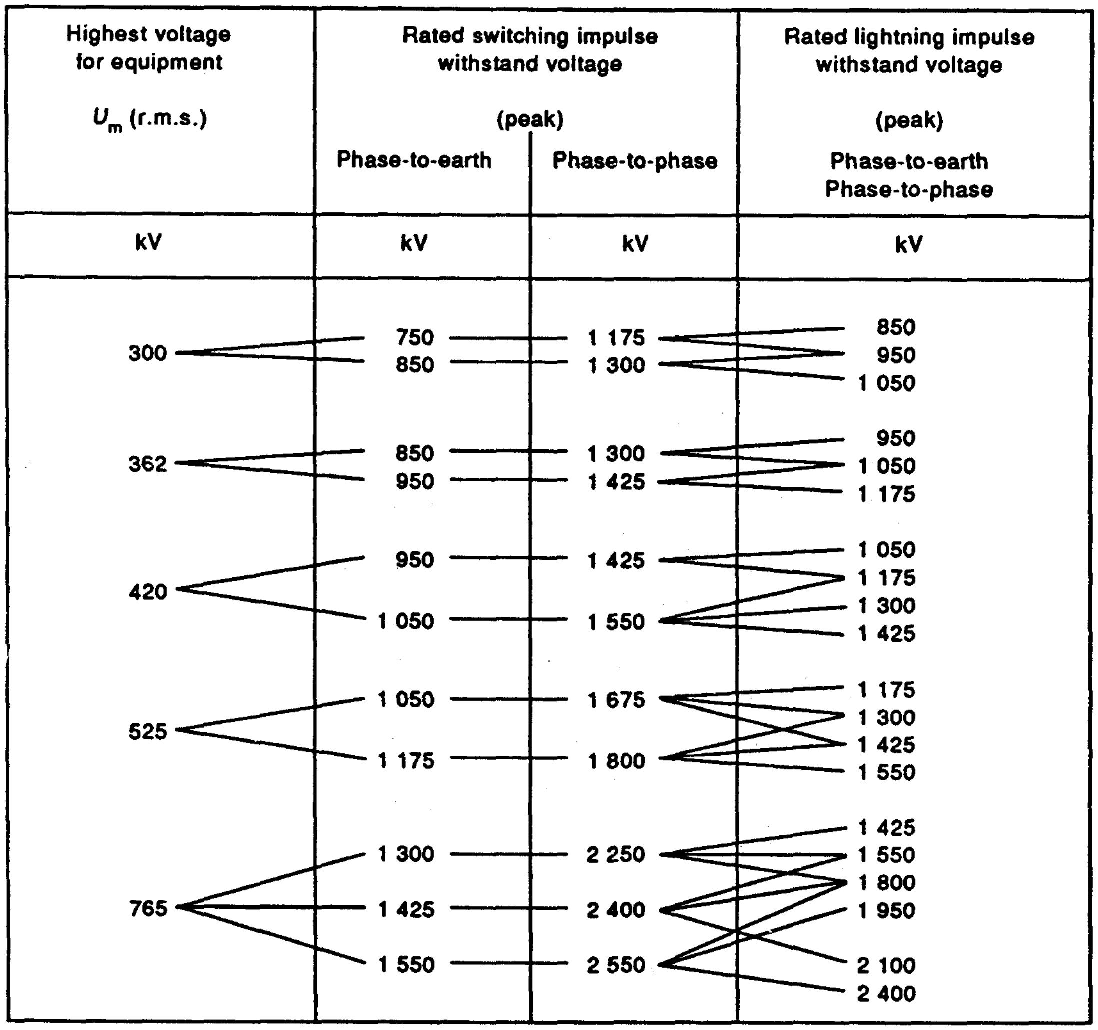
Highest voltage for equipment U_m (r.m.s.)	Rated lightning impulse withstand voltage (peak)	Rated short duration power-frequency withstand voltage (r.m.s.)
kV	kV	kV
1,3	30 *	6
2,75	45 *	13
5,5	75	24
15,5	95	30
19,8	125	36
27,5	150	50
38,0	200	70
48,3	250	95

* Does not apply to non-exposed circuits

Table 5 – Standard insulation levels for 52 kV ≤ U_m < 300 kV. The phase-to-phase test voltages in brackets should not normally be used (see IEC 71-3)

Highest voltage for equipment U_m (r.m.s.)	Rated lightning impulse withstand voltage (peak)		Rated short duration power-frequency withstand voltage (r.m.s.)	
	Phase-to-earth	Phase-to-phase	Phase-to-earth	Phase-to-phase
kV	kV	kV	kV	kV
52	250	250	95	95
72,5	325	325	140	140
123	450	450	185	185
	550	550	230	230
145	450	(450)	185	230
	550	550	230	230
	650	650	275	275
170	550	(550)	230	275
	650	650	275	275
	750	750	325	325
245	650	(650)	275	360
	750	(750)	325	360
	850	850	360	360
	950	950	395	395
	1 050	1 050	460	460

Table 6 – Standard insulation levels for $U_m \geq 300$ kV



Highest voltage for equipment U_m (r.m.s.)	Rated switching impulse withstand voltage (peak)		Rated lightning impulse withstand voltage (peak) Phase-to-earth Phase-to-phase
	Phase-to-earth	Phase-to-phase	
kV	kV	kV	kV
300	750 850	1 175 1 300	850 950 1 050
362	850 950	1 300 1 425	950 1 050 1 175
420	950 1 050	1 425 1 550	1 050 1 175 1 300 1 425
525	1 050 1 175	1 675 1 800	1 175 1 300 1 425 1 550
765	1 300 1 425 1 550	2 250 2 400 2 550	1 425 1 550 1 800 1 950 2 100 2 400

SECTION 4: OVERLOADS AND OVERVOLTAGES

4.1 Working currents

A series capacitor bank shall be suitable for operation at currents not exceeding 1,5 times the rated current I_N, subject to the following conditions:

- By definition of 7.2.1, the overcurrent shall not exceed:

  1,10 I_N for 8 h in a 12 h period

  1,35 I_N for 30 min in a 6 h period

  1,50 I_N for 10 min in a 2 h period.

- The average output of the capacitor bank over any service period of 24 h shall not exceed the rated output.

NOTE - The values correspond to minimum overload requirements. With certain network configurations, e.g. for lines operating in parallel, the requirements may be changed. In such a case, these new values shall be used when selecting the rated current according to 7.2.1.

4.2 Transient overvoltages

Series capacitors shall be suitable for repeated operations at transient overvoltages with the highest possible instantaneous value $\sqrt{2}\ U_{lim}$ that is expected to occur across the capacitor terminals (see 2.1.3). This expected magnitude of the overvoltage shall be agreed between the manufacturer and purchaser. The purchaser should give the estimated repetition rate.

SECTION 5: SAFETY REQUIREMENTS

5.1 Discharge device

Each capacitor unit or group of parallel units shall be provided with a means for discharging the residual voltage to 75 V or less from $\sqrt{2}\ U_N$. The maximum discharge time is 10 min for the capacitor unit or group of parallel units. There must be no switch, fuse, or any other isolating device between the capacitor unit(s) and the discharge device.

The discharge circuits must have adequate current carrying and energy absorbing capacity to discharge the capacitor from a voltage level equal to $\sqrt{2}\ U_{lim}$ and for auto-reclosing of the line and the series capacitor bank.

A discharge device is not a substitute for short-circuiting the capacitor terminals together and to earth before handling.

NOTES

1 Operating conditions above the rated voltage may cause a residual voltage over 75 V.

2 A fault in a unit cleared by a fuse, or a flashover across part of the bank can produce local residual charges inside the phase bank which cannot be cleared within the specified time by means of a discharge device connected between the terminals of the phase bank or segment.

3 In certain countries, a shorter discharge time and a lower residual voltage are required. In this case, the purchaser shall inform the manufacturer.

4 The service requirements may require that the phase banks or segments should be equipped with an additional discharge device.

5.2 Container connection

To enable the potential of the metal container of a capacitor unit to be fixed, and to be able to carry the fault current in the event of a breakdown to the container, the container shall be provided with connection means suited for a bolt with a screw size of at least M 10 or equivalent (e.g. brackets with unpainted mounting surface).

5.3 Protection of the environment

When capacitors contain materials (e.g. polychlorinated biphenyls) that must not be dispersed into the environment, the legal requirements of the country concerned shall be followed (annex C). The units and the bank shall be labelled accordingly, if so required.

5.4 Other safety requirements

The purchaser shall specify at the time of enquiry any special requirements with regard to the safety regulations applicable in the country in which the capacitor is to be installed.

SECTION 6: MARKINGS

6.1 Markings of the unit

6.1.1 *Rating plate*

The following information shall be given on the rating plate of each capacitor unit:

1) Manufacturer.

2) Identification number and year of manufacture; the year may be a part of identification number or be in code form.

3) Rated current I_N in amperes.

4) Rated capacitance C_N in microfarads.

5) Rated frequency f_N in hertz.

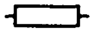
6) Rated voltage U_N in volts or kilovolts.

7) Rated output Q_N in kilovars.

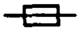
8) Limiting voltage U_{lim} in volts or kilovolts and type of the overvoltage protector (see 7.6.2), e.g., 9 kV (K).

9) Temperature category.

10) Discharge device, if internal, shall be indicated by wording or by the symbol

 or by the rated resistance in kilohms or megaohms.

11) Insulation level U_i in kilovolts.

12) Internal fuses, if included, shall be indicated by wording or by the symbol 

13) Chemical or trade name of impregnant; this indication may alternatively be stated on the warning plate (see 6.1.2).

14) Reference to IEC 143 (plus the year of issue).

A place shall be reserved for the measured capacitance (see 2.3.1). This value may be indicated in one of the following ways:

– as an absolute capacitance value which may replace the rated capacitance;

– as a difference ΔC between the measured and the rated capacitance indicated, for example, by symbols for the capacitance deviation ranges as follows:

++ for ΔC between +7,5 % and +4,5 %
+ for ΔC between +4,5 % and +1,5 %
+– for ΔC between +1,5 % and –1,5 %
– for ΔC between –1,5 % and –4,5 %
–– for ΔC between –4,5 % and –7,5 %.

The insulation level can be marked by means of two numbers separated by a stroke, the first number giving rated short duration power-frequency withstand voltage in kilovolts and the second number giving rated lightning impulse withstand voltage in kilovolts, e.g. 28/75 kV. For units having one terminal permanently connected to the container and not tested according to clauses 2.10 and 2.11, this information is not applicable.

6.1.2 *Warning plate*

If the capacitor unit contains material which may pollute the environment or may be hazardous in any other way (e.g. inflammability), the unit shall be provided with a label or otherwise marked according to the relevant laws of the country of the user. The purchaser shall inform the manufacturer about such law(s).

6.2 Markings of the bank

6.2.1 *Instruction sheet or rating plate*

The following minimum information shall be given by the manufacturer in an instruction sheet or alternatively, on contractual agreement, on a rating plate:

1) Manufacturer.
2) Rated output Q_N (e.g. 3 x 10 Mvar).
3) Reactance of each phase.
4) Rated current I_N.
5) Permissible overcurrent during 10 min (clause 4.1).
6) Rated voltage U_N.
7) Limiting voltage U_{lim}.
8) Insulation level with respect to earth.
9) Time to discharge the phase bank from $\sqrt{2}\ U_N$ to 75 V.
10) Type of the overvoltage protector (see 7.6.2).
11) Permissible symmetrical short-circuit current and its duration.

If further information is given in an instruction sheet the rating plate (or another plate if a rating plate does not exist) shall bear reference to this instruction sheet.

If the capacitor bank consists of series-connected segments, items 3, 6, 7 and 9 shall be related to each segment.

The insulation level can be marked by means of two numbers separated by a stroke, the first number giving the rated short duration power-frequency withstand voltage (for $U_m < 300$ kV) or the rated switching impulse withstand voltage (for $U_m \geq 300$ kV) in kilovolts, and the second number giving the rated lightning impulse withstand voltage in kilovolts, e.g. 185/450 kV.

6.2.2 *Warning plate*

6.1.2 is also valid for the bank.

SECTION 7: GUIDE FOR SELECTION OF RATINGS, AND FOR INSTALLATION AND OPERATION

7.1 General

Since series capacitors reduce the inductive line reactance, and thereby decrease the phase angle between the voltages at the ends of the line, they are used in long transmission lines to improve voltage regulation and system stability, and so to increase transmission capacity of the line. They are also used for governing the active power distribution between lines working in parallel thereby reducing the total transmission losses.

Because of their automatic and instantaneous response, series capacitors are used in distribution lines to reduce rapid voltage fluctuations due to load variation. Consequently, the voltage conditions in the system are improved in most cases.

Because of the fluctuating line current, series capacitors are subjected to much greater variation of the voltage between terminals than shunt capacitors. When a short-circuit occurs in the system, this voltage may be so high that capacitor units designed to withstand it would be uneconomical. Therefore such overvoltages are in most cases limited by an overvoltage protector which by-passes the phase bank or segment.

The effect of series capacitors on the system and their operating conditions are different in almost every application. To attain the best technical and economic results, each particular case should be studied individually in co-operation between the manufacturer and purchaser.

7.2 Choice of rated current and voltage ratings

7.2.1 *Rated current*

The load current of a series capacitor varies generally in normal working conditions. Moreover, during and following a system disturbance, swing and emergency currents will appear. Figure 3 gives an example.

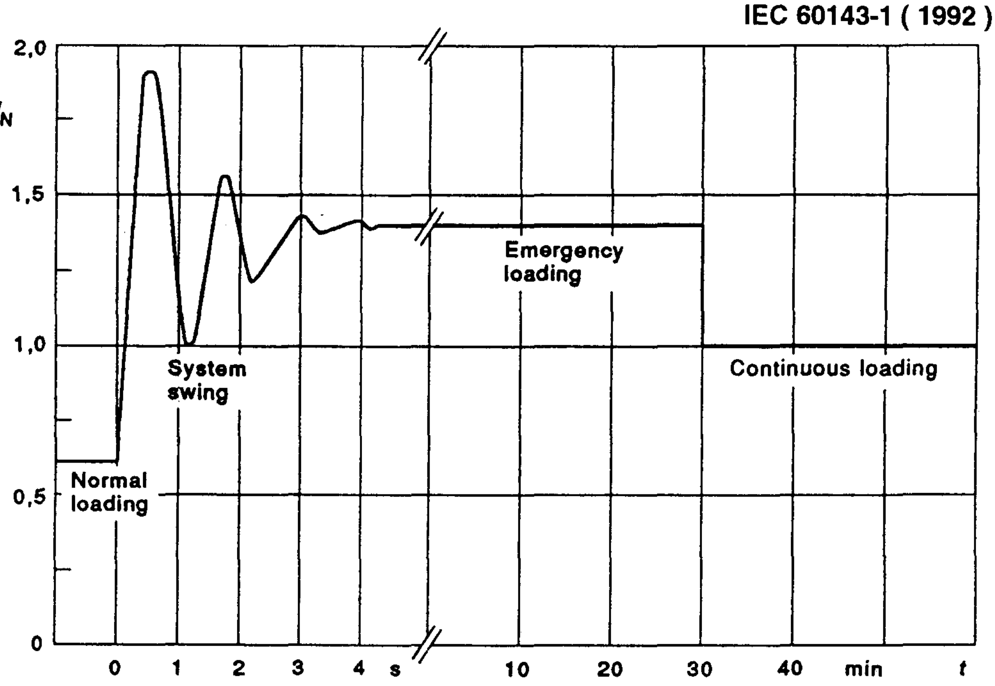


Figure 3 – Typical current swing on reinsertion of series capacitor after fault and loss of parallel line

The rated current I_N of the bank is chosen in relation to the results of an analysis of the expected current-time profile. The rated current should be selected on the basis of the following four requirements (clause 4.1):

- the highest through current (excluding transients) sustaining not more than 10 min, divided by 1,5;
- the highest through current sustaining more than 10 min but not exceeding 30 min, divided by 1,35;
- the highest through current sustaining more than 30 min but not exceeding 8 h, divided by 1,1;
- the average output of the capacitor over any period of 24 h shall not exceed the rated output.

NOTE - If any analysis of the expected current-time profile should not be practicable following the procedure laid down above, the rated current I_N should be chosen by agreement between the manufacturer and purchaser.

7.2.2 *Voltage ratings*

The requirements for the dielectric strength of the insulation between terminals are specified by two principal voltages:

- the rated voltage U_N which relates to normal operation (see 1.3.17);
- the limiting voltage U_{lim} which relates to transient voltages due to fault or abnormal conditions in the system (see 1.3.21 and clause 4.2).

There is no fixed relation between U_{lim} and U_N.

7.3 Capacitance

7.3.1 *Capacitance tolerance*

If the net reactances in the three phases of a line are different, differing phase voltages will appear at the receiving end of the line, and the neutral point of the voltage system will be displaced. This may give rise to undesirable effects in transformers and other apparatus. If the neutral points are earthed, earth currents may circulate.

Subclause 2.3.2 allows a certain difference between the phase capacitances. However, for the reasons mentioned, it is recommended that the capacitance differences should be as small as possible. In banks consisting of many units, this can be easily attained by distributing the units suitably over the phases.

7.3.2 *Capacitance variation with temperature*

Depending on design of the capacitor, its capacitance will vary more or less with temperature. The largest change of capacitance usually occurs immediately after energization. The warming up of the capacitors and thus the capacitances may then be unbalanced which can cause undue operation of the relay protection.

7.4 Operating temperature

Attention should be paid to the upper operating temperature of the capacitor, because this has a great influence on its life.

7.4.1 *Installation*

Capacitors should be so placed that there is adequate dissipation by convection and radiation of the heat produced by the capacitor losses. The ventilation of any enclosure and the arrangement of the capacitor units shall provide good air circulation around each unit. The temperature of capacitors subjected to radiation from the sun or from any high-temperature surface will also be increased.

Capacitors installed at high altitudes (more than 1 000 m) will have a reduced heat dissipation and the container temperature rise will increase. The ambient temperature, however, is generally lower at such an altitude.

7.4.2 *High ambient air temperature*

Capacitors for symbol C are suitable for the majority of applications under tropical conditions. In some locations, however, the ambient air temperature may be such that capacitors for symbol D are required. The latter may also be needed for those cases where the capacitors are regularly subjected to radiation of the sun for several hours, e.g., in desert territories, even though the ambient air temperature is not excessive. In exceptional cases, the ambient air temperature may be higher than the +55 °C maximum, or the +45 °C daily mean. Where it is impossible to improve the cooling conditions, capacitors of special design or with a decreased power density should be chosen.

7.5 Special conditions

In addition to the conditions covered in clause 7.4, the manufacturer should be advised by the purchaser of any special service conditions.

a) High relative humidity:

The specific creepage distance (clause 3.2) shall be selected accordingly. Attention is drawn to the possibility of external fuses being shunted by a deposit or moisture on their surfaces.

b) Rapid mould growth:

Metals, ceramic materials and some paints and lacquers do not support mould growth. When fungicidal materials are used, they do not retain their poisoning property for more than several months. In any case, mould may develop in an installation on places where dust, etc., can settle.

c) Corrosive atmosphere:

Such atmosphere is found in industrial and coastal areas. It should be noted that in climates of higher temperature, the effects of corrosive atmospheres may be more severe than in temperate climates. Highly corrosive atmospheres may be present also for indoor applications.

d) Pollution:

When capacitors are mounted in a location with a high degree of pollution, the specific creepage distance (clause 3.2) shall be selected accordingly.

e) Altitude exceeding 1 000 m:

Capacitors used at an altitude exceeding 1 000 m are subjected to special conditions. The choice of the type should be made by agreement between the manufacturer and purchaser (see 7.4.1 and 7.7.2).

f) Earthquakes:

In some areas there is a higher probability of earthquakes, which may effect the mechanical design of series capacitors to be installed in such areas. The purchaser shall specify the acceleration value and response spectrum.

7.6 Protective and switching devices

7.6.1 *Capacitor fuses*

The capacitor fuses are in principle of two kinds: internal fuses for each element or group of elements, and external fuses for each unit or parallel group of units.

If relay protection is arranged for internal faults in the bank, e.g. unbalance protection, it is recommended that this be set to trip when the voltage of the sound units exceeds more than 10 % of the value appearing under sound state. The fuse characteristics shall be properly co-ordinated with the relay protection, i.e. the fuses shall operate before the relay.

7.6.1.1 *Internal element fuses*

The purpose of the internal fuse is to isolate a punctured element and thus ensure undisturbed service of the faulty unit and the bank in the case of such a minor fault. Operation of more fuses in a unit may necessitate disconnection of the bank. A faulty unit can be found by capacitance measurements within a limited part of the phase bank without removing the wiring.

The detailed requirements for the internal fuses are found in IEC 595.

7.6.1.2 *External unit fuses*

The purpose of the external fuse is to isolate a unit if this has become partly or completely short-circuited. The external fuse will operate only when the number of punctures in elements in the failing capacitor unit has exceeded a given level. The external fuse is most often equipped with a signalling device by means of which the faulty unit can be found. Operation of some few external fuses (in certain cases only of one fuse) necessitates disconnection of the bank especially if there is only a small number of units directly in parallel.

The detailed requirements for the external fuses are found in annex A.

7.6.2 *Overvoltage protector*

Four types of overvoltage protector are used for rapid limiting of the overvoltages across the series capacitor terminals:

- type K - spark gap with sustained arc;
- type L - spark gap with repetitive arc (self-extinguishing gap); the repetitive functioning of the gap usually starts at a voltage below $\sqrt{2}\ U_{\text{lim}}$ (typical values 0,3 to 0,6 times $\sqrt{2}\ U_{\text{lim}}$ but above $\sqrt{2}\ U_{\text{N}}$);
- type M - non-linear resistor;
- type N - thyristor-type short-circuiting device.

NOTES

1 If the sparkover voltage of an overvoltage protector is dependent on air density, U_{lim} is understood to correspond to the conditions resulting in the highest sparkover voltage, i.e., to the highest air pressure and the lowest temperature. Also, the tolerance on sparkover voltage should be taken into account when determining U_{lim}.

2 The possibility of using no overvoltage protector also exists. This may be the case when the fault current is low and/or it is technically more advantageous to overdimension the capacitor instead of installing an overvoltage protector, e.g. in the case of very small capacitor banks. The details in such a case should be agreed upon and be based on the conditions according to clause 4.2.

3 In order to ensure a rapid reinsertion of the bank, a combination of two type K spark gaps may be used.

7.6.2.1 *Type K overvoltage protector*

When the gap sparks over due to an excessive line current caused by a fault in the system, an arc is sustained until de-energizing the line or closing a by-pass switch.

During arcing of the gap, the capacitor is exposed to one voltage peak whose value shall not exceed $\sqrt{2}\ U_{lim}$. The capacitor is subjected to a discharge transient once only at every operation of the gap.

The peak value of the discharge current should be limited to 100 times the rated (r.m.s.) current of the capacitor. See, however, 7.6.3.

7.6.2.2 *Type L overvoltage protector*

When the gap sparks over due to an excessive line current caused by a fault in the system, the arc is extinguished at current zero, thus permitting repeated sparkover of the gap during the fault. The means for obtaining this spark-gap operation sequence may be pneumatic and/or magnetic. For final extinguishing of the arc, it is not necessary to de-energize the line nor to close a by-pass switch. For this reason, a lower gap setting may be chosen than with the type K overvoltage protector.

During gap operation, the capacitor is exposed to both high overvoltages, especially when the repetitive sparkovers take place at a high voltage, and to repeated discharges.

The peak value of the discharge current should be limited to 50 times the rated (r.m.s.) current of the capacitor. See, however, 7.6.3.

7.6.2.3 *Type M overvoltage protector*

The non-linear resistor is permanently connected across the capacitor terminals. When the bank is operated at normal load current a given but very low current passes through the non-linear resistor.

In the case of a fault external to the line concerned, the series capacitor becomes automatically reinserted when the fault disappears. Even during such a fault the series capacitor exerts a certain compensating effect. For this reason, in many cases the U_{lim} chosen with type M can be lower than with types K and L overvoltage protectors. On the other hand, in the event of a short circuit at the compensated line itself, the breakers at the ends of the line will be opened, and such an automatic reinsertion is of no use.

The non-linear resistor shall be designed to withstand the thermal stresses occurring during the overload conditions according to clause 4.1, during the system swing according to 7.2.1 and those of the maximum line fault current at a voltage of $\sqrt{2}\ U_{lim}$.

In the event of prolonged duration of an external fault, e.g., due to malfunction of the line protection, the non-linear resistor may become thermally overloaded. Also short-circuits at the compensated line may imply such high currents that it is not economical to dimension the non-linear resistor accordingly. In order to protect the non-linear resistor in such cases, it may be by-passed by a switch or triggered spark-gap.

The peak value of the discharge current should be limited to 100 times the rated (r.m.s.) current of the capacitor. See, however, 7.6.3.

7.6.2.4 *Type N overvoltage protector*

Type N overvoltage protector is a thyristor device. There exist two modes of operation:

- Type N1 where the thyristor device remains short-circuited after the first ignition and throughout the total fault time. The U_{lim} value and the discharge current can be chosen as in the case of type K protector.
- Type N2 where the thyristor device restores after each overvoltage half-cycle and reignites at the next over-voltage. The U_{lim} value and the discharge current can be chosen as in the case of type L protector.

7.6.3 *Damping circuits for discharge current*

The damping rate of the discharge current shall be such that the current decays in a few milliseconds, in order not to overstress the fuses. The ratio between the second and the first discharge current amplitudes of the same polarity is usually chosen in the range of 0,4 to 0,5 but values up to 0,7 may be used. The maximum current values according to 7.6.2 apply. The selected damping rate shall be agreed upon between the manufacturer and the purchaser.

For all types of overvoltage protectors, other factors (such as the discharge current capability of the by-pass switch) may call for limiting the discharge current amplitude to a lower level than the values indicated in 7.6.2. In such a case, a lower current may be applied in the discharge current test (clause 2.13). On the other hand, if all components in the discharge path permit, higher discharge currents may be permissible, and the current applied during the discharge current test could be raised correspondingly. These special cases shall be agreed upon between the manufacturer and purchaser.

7.6.4 *Other devices*

For large series capacitor banks, a by-pass switch (a circuit-breaker or a load switch) is used to short-circuit the capacitor in the event of prolonged operation of the overvoltage protector or in the event of prolonged overvoltage not sufficient to cause the gap to operate. Such overvoltages may be produced by overloads or by sub-synchronous oscillations in the system (clause 7.8). The discharge current through the switch, when closed at $\sqrt{2}\ U_{\text{lim}}$, should be limited to the extent recommended for the relevant overvoltage protector in 7.6.2.

The by-pass switch must withstand the stresses occurring when switching the capacitor, and due regard shall be paid to the risk of restrikes.

For inspection and maintenance of large banks, disconnectors should be provided to disconnect the bank without interrupting operation of the line.

To avoid sustained voltage increase on parts of the bank due to failure of units, or flashovers, unbalance protection for each phase bank or segment may be used. Since some types of fault to the platform insulated from earth cannot be detected either by the unbalance protection, or by the relays at the line ends, in addition a fault-to-platform protection may be used.

7.6.5 *Connection diagrams*

Some examples of connection diagrams are shown in annex B.

7.7 Choice of insulation level

7.7.1 *Normal cases*

The insulation level of a series capacitor bank shall be chosen in accordance with that of the system to which the bank will be connected according to clause 3.1. A clear distinction should be drawn between the insulation level of the phase bank or segment and that of the units. The following possibilities should be considered:

- The insulation level of the units, based on the highest voltage that can occur between the terminals and container of any unit in the phase bank, is not less than that of the phase bank. Extra insulation (external to the units) need not then be employed.

- The insulation level of the units is less than that of the phase bank. Extra insulation (external to the units) is necessary with respect to earth for the metal supporting structures not at earth potential, and between series-connected units, if any. Unless the voltage distribution between the units is known, all external insulation should correspond to the insulation level of the phase bank. If, however, the voltage distribution is known, test voltages should be chosen in accordance with clause 3.1.

Some parts of the damping circuit will in normal operation have a very low voltage across its terminals and to surrounding metalwork. When the overvoltage protector operates, these parts may be subjected to high voltage surges, which shall be considered when determining their insulation level. See the note to 3.1.4.

7.7.2 *Altitude exceeding 1 000 m*

Insulation levels chosen according to clause 3.1 might be too low for external insulation at an altitude higher than 1 000 m (see 1.4.1). The purchaser should in such a case specify which insulation level is required when referred to normal test conditions. The requirements of clause 3.1 are still valid, but for the new specified insulation level.

For units with the container as one terminal, the manufacturer should provide evidence that the external insulation of the bushing withstands the test voltages corresponding to the site altitude.

7.8 Disturbing phenomena

7.8.1 *General*

The natural frequency of a system containing a large series capacitor is generally below the rated frequency. This entails the possibility that resonance phenomena below the rated frequency may occur under certain conditions. Since the probability of occurrence of such phenomena depends on many circumstances, each case should be studied separately.

7.8.2 *Ferro-resonance*

Due to saturation effects in iron, the inrush current may initiate sustained resonant oscillations with a sub-harmonic frequency. This phenomenon may occur when an unloaded transformer or a shunt reactor is switched on a series-compensated system during light load, particularly following load rejection.

7.8.3 *Self-excitation of motors*

During starting of an asynchronous motor, its inductance increases and the frequency of the rotor current decreases. At a certain speed, this frequency becomes equal to the natural frequency of the system. A resonant current may arise which excites the motor to act as an asynchronous generator when its speed corresponding to resonance is somewhat exceeded.

7.8.4 *Sub-synchronous resonance*

Sub-synchronous resonance is an electro-mechanical shaft oscillation phenomenon at sub-synchronous frequency which may occur between a series capacitor and large turbine generator(s).

7.8.5 *Hunting*

Hunting means sustained periodic variations of the rotor speed from the synchronous speed. Hunting may occur between generators or between generator and synchronous machines at a sudden change of load.

7.8.6 *Periodically varying load*

If the load varies periodically, the voltage fluctuations may be amplified by a series capacitor. Such a situation may be encountered e.g. when a big motor is driving a frame saw mill, which represents a periodically varying torque.

7.8.7 *Relay protection of the system*

Attention should be paid to the fact that a series capacitor may disturb the working of relays used for protection of the system, especially impedance protection.

7.8.8 *Attenuation of carrier-frequency transmission*

A series capacitor bank may increase attenuation of the carrier-frequency transmission over the line, depending on location and parameters of the damping circuits.

Annex A
(normative)

Test requirements and application guide for external fuses and units to be externally fused

A.1 Scope

Annex A applies to external fuses used with series capacitors.

There exists no IEC standard for the external fuses for protection of series capacitors. However, IEC 549 can be used as the basis when duly applied. For example, the selection of the rated voltage and current of the fuse shall be based on the permissible overloads (clause 4.1) and their behaviour at discharge currents on those of the series capacitors.

A.2 Object

The object of annex A is:

- to specify rules regarding testing and performances of external fuses;
- to provide a guide for the application of external fuses.

A.3 Definitions

See IEC 549 and 1.3.12.

A.4 Performance requirements

a) The performance requirements of the fuse shall in principle be in accordance with IEC 549, but duly applied to the case of series capacitors.

b) The external fuse shall operate satisfactorily at voltages from 0,5 U_N to U_{lim}.

c) The external fuses have to withstand the overcurrents according to clause 4.1 and the conditions prevailing under the thermal stability test (clause 2.9). The fuse intended for a unit shall be in the circuit (and thermal enclosure) during the thermal stability test, or it may be type-tested separately under equal or more severe conditions.

d) The external fuses have to withstand the currents met in the discharge current test (clause 2.13). The fuse intended for a unit shall be in the circuit during the discharge current test, or it may be type-tested separately under equal or more severe conditions.

e) External fuses for groups of units shall be type tested separately under equal conditions as described above. The electrical conditions for the fuse shall be such as if the complete group of units with fuse were being tested.

f) After the operation of an external fuse the insulation level requirements (see clause 3.1) apply either for the fuse itself or for the created insulation distance. For an external fuse which will not be physically disconnected after its operation the creepage distance requirements (see clause 3.2) also apply.

g) For an external fuse which is equipped with a device that will disconnect the fuse physically after its operation and/or for an external fuse which will eject gases (or other materials) during its operation, the insulation conditions within the bank shall also be considered during the fuse operation period.

A.5 Tests

A.5.1 *Tests on fuses*

See IEC 549.

A.5.2 *Type tests on capacitor container*

Under consideration.

A.6 Guide for co-ordination of fuse protection

A.6.1 *General*

Each fuse is connected in series with one unit or one group of units which the fuse is intended to isolate if a unit becomes faulty.

NOTES

1 Depending on the phase bank arrangement and internal connections of the unit, the current through the faulty unit due to its failure, together with the current due to the discharge of stored energy in units connected in parallel with the faulty unit, is usually not sufficient to operate the fuse until several of the series-connected elements of the faulty unit have failed. In order to ensure that the fuse will operate and isolate a completely failed unit, the fuse should be rated so that it operates when subjected solely to the resulting power-frequency overcurrent at 0,5 times the rated line current which would flow in the partly short-circuited unit.

2 The operation of one or more fuses will cause a change in voltage distribution within the phase bank. The voltage across the sound units should not exceed the value corresponding to clause 4.1 nor exist for longer than the corresponding duration given in clause 4.1. Unless arrangements are made for the disconnection of the bank to achieve this requirement, all the units in the bank should be rated appropriately for the more severe duty arising from the disconnection of units due to operated fuse(s).

3 For units with series-connected elements, the puncture of an element causes voltage distribution changes within the bank and within the unit to occur before fuse operation. These voltage changes should also be considered with respect to sequential operation of the protection of the bank.

A.6.2 *Protection sequence*

The protection of a series capacitor bank should operate sequentially. Normally the first step is operation of the unit (group) fuse. The second step is the relay protection of the bank (e.g. unbalance protection). The third step may be the network protection.

NOTES

1 Depending on the size of the bank, the design of the relay protection, etc., all these steps are not necessarily used in all series capacitor banks.

2 In large banks, an alarm stage may also be used.

3 Unless the fuse always operates as a result of discharge energy within the voltage range of 0,5 $\sqrt{2}\,U_N$ to $\sqrt{2}\,U_{lim}$, the manufacturer shall provide the time-current characteristic, and tolerance on the fuse.

4 In some cases, the unbalance protection is more sensitive than the fuses, implying fuse operation only at, for example, flashover across the bushing or complete breakdown of the dielectric of the unit. In such a case, the unbalance protection is the first step, and the fuse(s) act(s) as back-up protection.

A.7 Choice of fuses

A.7.1 *General*

When selecting fuses, consideration should be given to minimize the probability of container rupture in the event of a capacitor unit failure by making use of the best available data and guidelines. The data and the guidelines employed shall be agreed upon by the manufacturer and purchaser. This requirement refers to power-frequency overcurrent as well as to stored energy in the units parallel with the failed unit.

Care should be taken in selection of the fuses of the electrical and thermal conditions imposed on them should they be in circuit during the type tests of clauses 2.9 and 2.13.

A.7.2 *Non current-limiting fuses*

Non current-limiting fuses are usually of expulsion type, with renewable fuselinks. They have little or no current limiting action for either power-frequency current or stored energy discharge.

The total energy stored in the capacitor units in parallel with the failed unit should be less than the fuse can discharge without exploding, and less than the energy causing the failed unit to burst (A.7.1).

This type of fuse may be used where the power-frequency overcurrents which can be supplied to the faulty unit are sufficiently low.

A.7.3 *Current-limiting fuses*

This type of fuse will limit power-frequency overcurrents to less than the prospective value and will reduce the current to zero before the normal current zero. A properly selected current-limiting fuse will discharge only a portion of the stored energy available to the failed capacitor unit. The amount let through by the fuse shall be less than that causing the failed unit to burst.

Current-limiting fuses should be used when either the power-frequency overcurrent or maximum stored energy in the units parallel with a failed unit is high enough to cause bursting of an expulsion fuse or a failed capacitor unit. Properly selected current-limiting fuses impose no upper limit on the stored energy available to a failed unit.

A.8 Information needed by the user of the fuses

To be able to choose the right fuse for each application, it may be necessary to refer to some or all of the information given in IEC 549.

Annex B
(informative)

Some examples of connection diagrams of phase banks or segments

The combinations of bank or segment size and type of overvoltage protector shown are only examples. Other combinations are also possible.

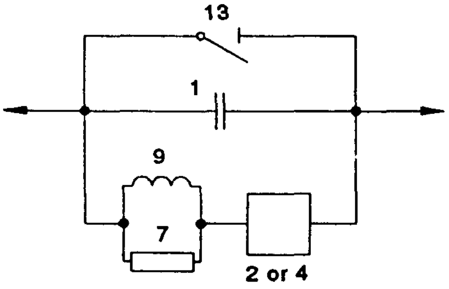


Figure B1 – Phase bank size of the order of 300 kvar

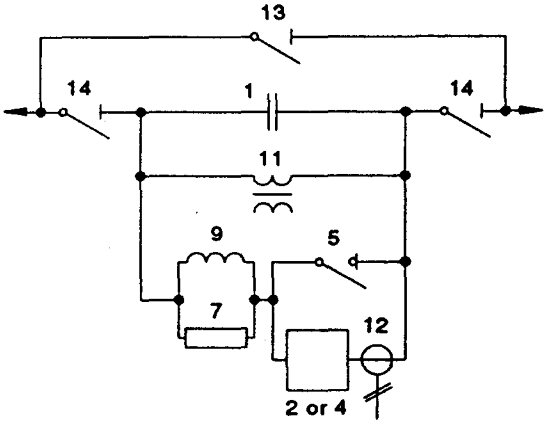
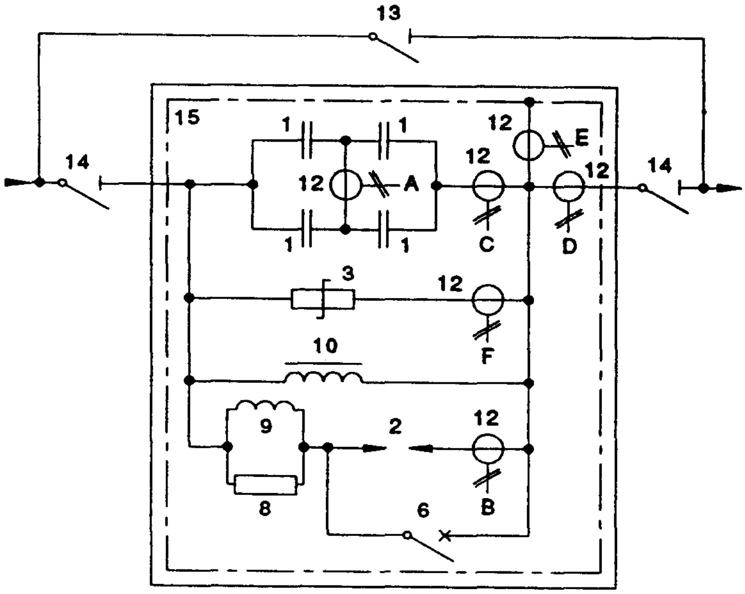


Figure B2 – Phase bank size of the order of 2 Mvar



Purposes of the current transformers:

A = Unbalance protection

B = Gap current check

C = Unbalance and overcurrent protection

D = Sub-harmonic protection, reinsertion control, supply of platform power source

E = Fault-to-platform protection

F = Overload protection of non-linear resistor

Figure B3 – Phase bank or segment size larger than 10 Mvar (the spark gap acts in this case as back-up protection for the non-linear resistor)

1 Capacitor
2 Spark gap (type K or L)
3 Non-linear resistor (type M)
4 Thyristor device (type N)
5 Circuit-breaker or load switch
6 Circuit-breaker
7 Damping resistor which may be omitted if reactor 9 has a low Q value
8 Damping resistor
9 Damping reactor
10 Discharge reactor (if any)
11 Voltage transformer
12 Current transformer
13 By-pass switch
14 Series disconnector
15 Platform (insulated from earth)

Annex C
(informative)

Precautions to be taken to avoid pollution of the environment by polychlorinated biphenyls

The disposal of polychlorinated biphenyls (PCB) without the necessary precautions may involve pollution of the environment. In addition, when a PCB impregnated capacitor unit has been exposed by accident to heat by fire or by an arc, toxic substances may form in the combustion process that may pollute the areas adjacent to the capacitor.

In some countries, the characteristics of PCB used in the impregnation of capacitors and the methods employed for their handling and destruction are governed by laws, or by codes of practice (see 6.1.2).

Annex D
(informative)

Bibliography

IEC 44-4: 1980, *Instrument transformers – Part 4: Measurement of partial discharges.*

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act,* 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

This Indian Standard has been developed from Doc : No. ET 29 (3592).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002
Telephones : 323 01 31, 323 33 75, 323 94 02

Telegrams: Manaksanstha
(Common to all offices)

Regional Offices :	Telephone
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	323 76 17 323 38 41
Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Kankurgachi CALCUTTA 700 054	337 84 99, 337 85 61 337 86 26, 337 91 20
Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160 022	60 38 43 60 20 25
Southern : C. I. T. Campus, IV Cross Road, CHENNAI 600 113	235 02 16, 235 04 42 235 15 19, 235 23 15
Western : Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400 093	832 92 95, 832 78 58 832 78 91, 832 78 92

Branches : AHMADABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM.

Printed at New India Printing Press, Khurja, India